Christ Church
Grammar School

Year 12 Chemistry

Extended Response 1
Test
2019

Time allowed: **45 minutes**

Name: Answers

Mark = .../40

Question 1 **(11 marks)**

Silicon tetrachloride is ($SiC\ell_4$) is a colourless liquid which reacts with water to form solid silicon dioxide (SiO_2) and hydrochloric acid as products. 5.12 g of silicon tetrachloride is added to an excess of water and the resultant solution is made up to exactly 250 mL.

(i) Write a balanced molecular equation for the reaction, including state symbols.

(2 marks)

$SiCl_{4(l)} + 2H_2O_{(l)} \rightarrow SiO_{2(s)} + 4HCl_{(aq)}$ ✓✓

(ii) Write an ionic equation for the same reaction

(1 mark)

$SiCl_{4(l)} + 2H_2O_{(l)} \rightarrow SiO_{2(s)} + 4H^+_{(aq)} + 4Cl^-_{(aq)}$ ✓

(iii) Calculate the concentration of hydrogen ions in the final solution, and hence its pH.

(4 marks)

$n(SiCl_4) = \frac{5.12}{169.89}$

$= 0.03014$ ✓

$\Rightarrow n(H^+) = n(SiCl_4) \times \frac{4}{1}$

$= 0.1205$ ✓

$\Rightarrow c(H^+) = \frac{0.1205}{0.25}$

$= 0.4822\ mol\ L^{-1}$ ✓

$\Rightarrow pH = -\log(0.4822)$

$= 0.32$ ✓

(iv) If 20.0 mL of the final solution is added to an excess of silver nitrate, calculate the mass of silver chloride precipitate that could be formed.

(4 marks)

$n(Cl^-)_{250mL} = 0.1205$ ✓

$\Rightarrow n(Cl^-)_{20mL} = 0.1205 \times \frac{20}{250}$

$= 0.009643$ ✓

$Ag^+ + Cl^- \rightarrow AgCl$

$\Rightarrow n(AgCl) = 0.009643$ ✓

$\Rightarrow m(AgCl) = (0.009643)(143.35)$

$= 1.38\ g$ (3 s.f.) ✓

Question 2 **(6 marks)**

Triethylaluminium, $(C_2H_5)_3Al$, is a very useful catalyst used extensively in the plastics industry. It is formed by the following series of reactions.

Reaction 1. Purification of the ore bauxite to form pure aluminium oxide, Al_2O_3.

Reaction 2. Electrolysis of aluminium oxide to form pure aluminium.

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

Reaction 3. Reaction with ethene and hydrogen at high pressure

$$2Al + 6C_2H_4 + 3H_2 \rightarrow 2(C_2H_5)_3Al$$

What mass of bauxite ore (containing 46% aluminium oxide) would be needed to produce 10.0kg of triethylaluminium. You may assume that steps 2 and 3 are both 100% efficient and that the hydrogen and ethene are both in excess.

$n((C_2H_5)_3Al) = \frac{10,000}{114.16}$

$= 87.596$ ✓

$\Rightarrow n(Al) = 87.596$ ✓

$\Rightarrow n(Al_2O_3) = n(Al) \times \frac{2}{4}$

$= 87.596 \times \frac{2}{4}$

$= 43.798$ ✓

$\Rightarrow m(Al_2O_3) = (43.798)(101.96)$

$= 4,466\,g$ ✓

$\Rightarrow m(bauxite) = m(Al_2O_3) \times \frac{100}{46}$

$= 9,708\,g$ ✓

$= 9,710\,g$ (3sf)

$= 9.71\,kg$ (")

✓

Question 3 **(15 marks)**

'Novichok' is general name for a series of nerve agents developed by Russia during the Cold War. It was allegedly used in the poisoning of a former spy and his daughter in the UK in 2018. Novichok agents contain up to six elements and have the general formula $C_tH_vP_wF_xO_yN_z$, where t,v,w,x,y and z are all integer values.

Analysis of a suspected sample of novichok yielded the following results.

Step 1. Complete combustion of a 0.0213 g sample in excess oxygen yielded 0.0168 g of carbon dioxide, 0.00516 g of water and 0.00439 g of nitrogen dioxide.

Step 2. Any fluorine in A 0.0477 g sample was converted into hydrogen fluoride gas (HF). The volume formed of this gas, measured at STP, was each 19.42 mL.

Step 3. A 0.269 g sample was treated to convert all the phosphorus present into a precipitate of magnesium phosphate, $Mg_3(PO_4)_2$ (molar mass, M= 262.84). The mass of the precipitate formed was 0.158 g.

(a) Use the above information to calculate the empirical formula of the sample.

C

$n(CO_2) = \frac{0.0168}{44.01}$

$= 0.000382$

$\Rightarrow n(C) = 0.000382$

$\Rightarrow m(C) = (0.000382)(12.01)$

$= 0.00458\,g$ ✓

$\Rightarrow \%C = \frac{0.00458}{0.0213} \times 100$

$= 21.52\%$ ✓ (2)

H

$n(H_2O) = \frac{0.00516}{18.016}$

$= 0.000286$

$\Rightarrow n(H) = (0.000286)(2)$

$= 0.000572$

$\Rightarrow m(H) = (\quad)(1.008)$

$= 0.000574$ ✓

$\Rightarrow \%H = \frac{0.000574}{0.0213} \times 100\%$

$= 2.71\%$ ✓ (2)

N

$n(NO_2) = \frac{0.00439}{46.01}$

$= 0.0000954$

$\Rightarrow n(N) = 0.0000954$ ✓

$\Rightarrow m(N) = (0.0000954)(14.01)$

$= 0.00133$

$\Rightarrow \%N = \frac{0.00133}{0.0213} \times 100$

$= 6.28\%$ ✓ (2)

F

$n(HF) = \frac{0.0194}{22.71}$

$= 0.000854$

$\Rightarrow n(F) = 0.000854$) (×19.00)

$\Rightarrow m(F) = 0.0162$

$\Rightarrow \%(F) = \frac{0.0162}{0.0477} \times 100$

$= 34.06\%$ (2)

$M(Mg_3(PO_4)_2) = \frac{0.158}{262.84}$

$= 0.000601$

$\Rightarrow n(P) = (0.000601)(2)$

$= 0.001202$ ✓

$\Rightarrow m(P) = (0.001202)(30.97)$

$= 0.03723_5$

$\Rightarrow \%P = \frac{0.269}{} \times 100$

$= 13.84\%$ ✓

$\%O = 100 - \%C - \%H - \%N - \%F - \%P$

$= 100 - 21.52 - 2.71 - 6.78 - 34.06 - 13.84$

$= 21.59\%$

C	H	N	F	P	O
21.52	2.71	6.78	34.06	13.84	21.59
1.792	2.688	0.48	1.791	0.447	1.349

$\div 0.447$

4.01 : 6.01 : 1.002 : 4.01 : 1 : 3.02

4 : 6 : 1 : 4 : 1 : 3

$C_4H_6NF_4PO_3$

(12 marks)

Finally, a 0.0121 g sample was vaporised at 258°C and 43 kPa and was found to occupy a volume of 5.58 mL.

$\frac{273.1}{531.1}$

(b) Use the above information to calculate the molecular formula of the sample

$n = \frac{(43)(0.00558)}{(8.314)(531.1)}$

$= 0.000054$

$\Rightarrow M = \frac{0.0121}{0.000054}$

$= 222.7$

$M(C_4H_6NF_4PO_3) = 223.068$

$\frac{M(ME)}{M(E)} = \frac{222.7}{223.068}$

$\simeq 1$

$\Rightarrow ME = E$

$= C_6H_6NF_4PO_3$

(3 marks)

Question 4 **(8 marks)**

Potassium percarbonate is a useful sterilising agent used in the food industry. It has a formula $xK_2CO_3.yH_2O_2$, where x and y are both integer values. When heated at 200°C, the H_2O_2 is removed, leaving behind solid anhydrous potassium carbonate. The following results were obtained;

- Mass of crucible before heating =15.49g
- Mass of heated crucible =12.46g
- Mass of crucible and potassium percarbonate =23.18g
- Mass of crucible and contents after 5 minutes reaction =21.17g
- Mass of crucible and contents after 10 minutes reaction =20.56g
- Mass of crucible and contents after 15 minutes reaction =20.29g
- Mass of crucible and contents after 20 minutes reaction =20.29g

(a) Why was the crucible heated before the potassium percarbonate was added?

to evaporate moisture etc.

(1 mark)

(b) Use the information above to calculate the values of x and y.

$m(H_2O_2) = 23.18 - 20.29$

$= 2.89g$

$\Rightarrow n(H_2O_2) = 0.08496$ ✓

$m(K_2CO_3) = 20.29 - 12.46$

$= 7.83g$

$\Rightarrow n(K_2CO_3) = \frac{7.83}{138.2}$

$= 0.05667$ ✓

	K_2CO_3	H_2O_2
n	0.05667	0.08496
	$\frac{0.05667}{0.05667}$	$\frac{0.08496}{0.05667}$ ✓
	1	1.4995
	1	$1\frac{1}{2}$
	2	3

$2K_2CO_3.3H_2O_2$ ✓

(4 marks)

Finally, stronger heating at a much higher temperature causes decomposition of the potassium carbonate to form solid potassium oxide and carbon dioxide gas.

(c) Write a balanced chemical equation for this reaction, including state symbols.

$K_2CO_{3(s)} \rightarrow K_2O_{(s)} + CO_{2(g)}$ ✓

(1 mark)

Assuming full decomposition, what would be the final mass of the crucible and contents after this reaction has occurred.

$n(K_2O) = n(K_2CO_3)$

$= 0.05667$ ✓

$\Rightarrow m(K_2O) = (0.05667)(94.2)$

$= 5.34\text{ g}$

$m(\text{crucible + contents}) = 5.34 + 12.46$ ✓

$= 17.80\text{ g}$

(2 marks)

END OF TEST